

EVAPORATION OF POTASSIUM AND SODIUM UNDER VACUUM CONDITIONS - DID CHONDRULES REALLY FORM AT LOW PRESSURE? Yang Yu and Roger H. Hewins. Dept. of Geological Sciences, Rutgers University, Piscataway, NJ 08855.

Introduction Potassium and sodium are both moderately volatile elements [1]. Though many experimental studies have been done to investigate the volatility of sodium and its implications to chondrule formation [e.g., 2,3], most of these experiments were performed at 1 atm pressure. There have been only limited studies on the volatility of potassium [4,5] and it is not clear how the evaporative behavior of potassium compares to that of sodium. Assuming chondrules formed in a nebular environment with pressures far less than 1 atm [6], a knowledge of the evaporative behavior of the moderately volatile elements at low pressures is important for understanding the chondrule-forming processes. Moreover, understanding the evaporative behavior of potassium is particularly important because potassium is a lithophile element with more than two isotopes, potentially a better candidate than sodium for studying nebular processes since it allows studies of mass dependent isotopic fractionation [7]. We report here our recent experimental results on the evaporative behavior of potassium and sodium at low pressures using newly established high temperature vacuum furnace facilities.

Experiments The evaporation experiments were performed on a Deltech muffle tube furnace with a vacuum system. The system is capable of achieving variable pressures from 1 to 10^{-9} atm (10^{-6} torr) with controlled gas species, and allows instantaneous heating and quenching as well as accurate control of sample heating time, heating temperature, and cooling rate. As a preliminary study, though, the experiments reported here were run under primary vacuum range ($\sim 10^{-2}$ – 10^{-3} torr). The sample used in the experiments was a synthetic silicate glass similar in composition to type IIAB chondrules but with K and Na enriched (3.3% K_2O and 2.8% Na_2O). The sample of about 50 mg was pressed into a pellet, and supported by a platinum wire on the sample holder. The experimental temperature was 1450°C, about 30°C above the sample liquidus. Three sets of experiments were performed: one in vacuum, one in vacuum+ H_2 , and one at 1 atm. In vacuum experiments, the furnace was preheated to the desired temperature and evacuated to 6×10^{-3} torr, then the sample was lowered into the furnace hot spot. The heating times ranged from 5 minutes to 2 hours. In the end, the sample was removed from the hot zone and quenched in vacuum. The fO_2 is unknown but estimated to be above iron-wustite buffer based on iron foil test. In vacuum+ H_2 experiments, the furnace was preheated and evacuated to 6×10^{-3} torr, then pure H_2 gas was introduced into the system at a rate such that the final pressure was at 7×10^{-2} torr. The rest of the experimental procedures are similar to those for the vacuum runs. In 1 atm experiments, the furnace was flushed with CO/CO_2 gas mixture. The fO_2 was controlled at 0.5 log units below iron wustite buffer. In all three sets of experiments, the final charge was clear

glass and roughly in oval shape. The mass loss of the sample was determined by weighing the sample before and after the heating experiments. The compositions of the final charges were determined with a JEOL-8600 electron microprobe. The acceleration voltage was at 15 kv. A rastered beam and shorter counting time was employed to minimize the Na and K loss from the sample.

Experimental results There are three major observations. First, pressure has a significant effect on the vaporization rates of both K and Na from silicate melt. The calculated vaporization rate of K at 1450°C, for example, is about an order of magnitude higher at 10^{-5} atm than that at 1 atmosphere pressure, e.g., 3.8×10^{-3} cm/min vs. 1.7×10^{-4} cm/min (Fig. 1). Second, the presence of H_2 enhances the K and Na loss. Introduction of H_2 into the evacuated system caused about an order of magnitude increase in overall system pressure, yet the vaporization rates for both K and Na are slightly increased. Third, Na has a higher vaporization rate than K. This is observed in all three sets of experiments run under different pressures and gas environment. On the K/K_o vs. Na/Na_o diagram (Fig. 2), the data of experimental charges significantly deviate from the 1:1 line and form a curve convex towards the K-rich side. The calculated values of vaporization rates for Na are about 1.3 to 2 factors higher than those for K.

Discussion Potassium and sodium have very similar condensation temperatures [1] but this does not necessarily lead to similar evaporation rates. An analogous situation exists with isotopes of K, which may or may not show mass fractionation during evaporation [7]. This study shows that when heated far above the minimum vaporization temperatures for both elements, sodium is more easily lost from chondrule melts.

Chondrules have various potassium and sodium contents and the two elements are positively correlated [8]. However, the chondrule data are more or less linear on K-Na plot and do not show a curve that convex towards the potassium rich side as shown in Fig. 2. This suggests that chondrules are unlikely to have formed by progressive evaporation from a single original source, unless the conditions that suppress K isotopic fractionation also suppress K/Na fractionation. There are other possibilities such as volatile recondensation [9] or low temperature re-entry [10], but how these processes can affect the K/Na ratio is unknown. Detailed potassium isotopic study should unveil the secrets and this will be the next step of our on-going investigation.

Compared to 1 atm pressure, potassium and sodium evaporate much faster at lower pressure and with the presence of H_2 , as in a nebular environment. Various hypotheses have been proposed to explain the relatively high sodium content of type II chondrules, including the flash heating model. Results obtained from 1 atm experiments are supportive of the flash heating scenario [3].

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However, we have performed a flash heating simulation experiment at 6×10^{-3} torr with the sample heated for 20 seconds and cooled at 5000°C/hr , and the charge lost 40% of sodium and 25% of potassium. More experiments are underway, but it becomes doubtful that flash heating alone will effectively prevent volatile loss under low pressure conditions.

References [1] Palme H. et al. (1988) In *Meteorites and the Early Solar System*, 436-461. [2] Tsuchiyama A. et al. (1981) *GCA*, 45, 1357-1367. [3] Yu Y. et al. (1996) In *Chondrules and the Protoplanetary Disk*, 213-219. [4] Gibson E. K. and Hubbard N. J. (1972) In *Proc. LSC 3rd*, 2003-2014. [5] Shimaoka T. and Nakamura N. (1991) In *Origin and Evolution of Interplanetary Dust*, 79-82. [6] Wood J. A. and Morfill G. E. (1988) In *Meteorites and the Early Solar System*, 329-347. [7] Humayun M. and Clayton R. N. (1995) *GCA*, 59, 2131-2148. [8] Grossman J. N. (1996) In *Chondrules and the Protoplanetary Disk*, 243-253. [9] Huang S. et al. (1994) *LPS XXV*, 573-574. [10] Grossman J. N. (1996) *LPS XXVII*, 467-468.

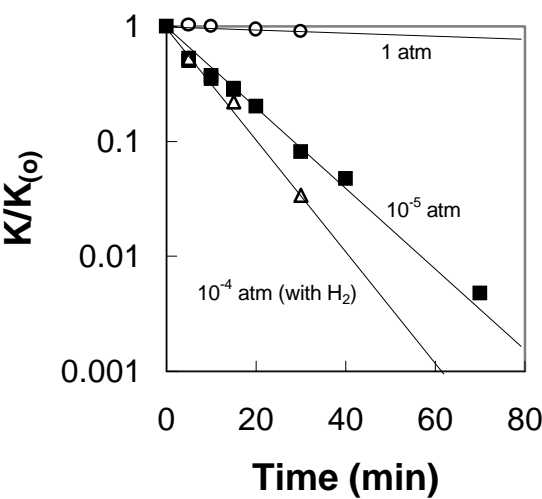


Figure 1.

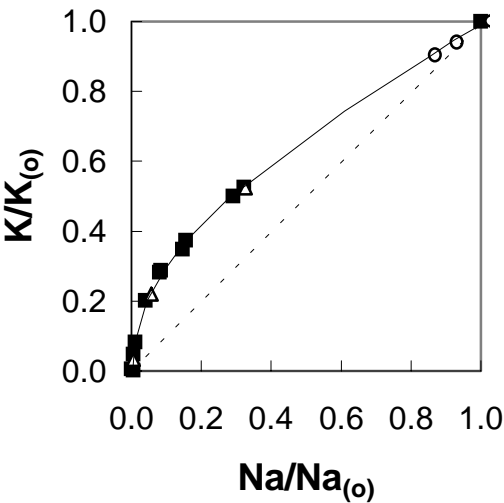


Figure 2.